Anonymous Referee #2
Citation: https://doi.org/10.5194/egusphere-2026-628-RC2

The manuscript “Causal and uncertainty-aware digital-twin framework for ultra–low-noise geoscientific inertial sensors” by Antonino D’Alessandro is well written and easy to follow. The digital twin framework developed in the manuscript appears sound and useful to me. The assumptions and potential shortcomings in the numerical models are clearly stated, e.g., no nonlinear effects or noise correlations are included.
I am not an expert on inertial sensors and cannot therefore comment adequately on the novelty of the approach presented here but trust the other reviewers to judge this aspect. I have no objections to the manuscript being accepted for publication once a few details are fixed.

I thank the reviewer for the positive assessment of the manuscript and for recognising the clarity of the presentation and the soundness of the proposed framework. I also appreciate the acknowledgment of the explicit discussion of assumptions and limitations. All specific comments aimed at improving clarity and presentation have been carefully addressed in the revised manuscript.

Moderate issue:
Line 154: Isn’t this a reference to figure 1 rather than figure 2? And speaking of figure 2, this figure showcasing open loop / closed loop performance isn’t discussed in the text.

The reference to Fig. 2 at line 154 is correct; however, I agree that the wording was potentially misleading, as the term “schematic representation” may be more naturally associated with Fig. 1. I have therefore revised the sentence to clarify that Fig. 2 illustrates the frequency-domain response of the system rather than its conceptual architecture.
In addition, I acknowledge that Fig. 2 was not explicitly discussed in the original text. In the revised manuscript, I have added a dedicated explanation describing the open-loop and closed-loop responses, highlighting the suppression of the mechanical resonance and the role of force-feedback control in shaping the system dynamics.
These modifications improve the clarity and consistency between the figures and the main text.

Minor issues
Line 154: Isn’t this a reference to figure 1 rather than figure 2? And speaking of figure 2, this figure showcasing open loop / closed loop performance isn’t discussed in the text.

The reference to Fig. 2 at line 154 is correct; however, I agree that the wording was potentially misleading, as the term “schematic representation” could be more naturally associated with Fig. 1, which illustrates the conceptual architecture of the system. I have therefore revised the sentence to clarify that Fig. 2 refers to the frequency-domain response of the system rather than its structural layout.
In addition, I acknowledge that Fig. 2 was not explicitly discussed in the original manuscript. In the revised version, I have added a dedicated description of the figure, highlighting the differences between open-loop and closed-loop responses, the suppression of the mechanical resonance under force-feedback control, and the corresponding behaviour of the force-balance transfer function.
These modifications improve the clarity and consistency between the figures and the main text.

Line 185: Would it be possible to add a reference to the “analytical treatments that neglect realisability constraints”?

I agree that supporting this statement with appropriate references improves the rigor and traceability of the argument.
In the revised manuscript, I have added references to classical treatments in linear systems and signal processing where idealised or non-causal representations are commonly employed, as well as to literature on inertial sensor modeling where simplified or unconstrained formulations are used for analytical tractability.

These additions clarify the context in which realisability constraints may be relaxed and better position the proposed framework with respect to existing analytical approaches.

Line 209, equation 1, a_g(t) is ground acceleration to be measured. In figure 1, this quantity is denoted by u-double-dot. Is there a reason for this choice (shift?) of notation?

The quantities $a_g(t)$in Eq. (1) and $\ddot{u}$ in Fig. 1 represent the same physical quantity, namely the ground acceleration. The use of different notations reflects a distinction between the formal system representation adopted in the equations and the more traditional kinematic notation used in the conceptual schematic.
To avoid ambiguity, I have clarified this point in the revised manuscript by explicitly stating the equivalence between the two notations.

Line 243: spaces are missing after mathematical notation.

I have corrected the spacing after mathematical expressions at the indicated location and performed a careful revision of the manuscript to ensure consistent formatting throughout.

Section 8 and 9. There is a lot of similarity between the discussion and the conclusion. It might be preferred to shorten one of these sections. If space is made available in the discussion section, it could be interesting and worthwhile to add an example or two with design considerations where the results from figure 4-7 come into play.

I agree that improving the balance between the Discussion and Conclusions sections enhances the clarity and impact of the manuscript.
In the revised version, I have reduced redundancy by streamlining the Conclusions section, focusing it on the main consolidated results and broader implications. The Discussion has been correspondingly refined to emphasise interpretation rather than repetition.
In addition, I have expanded the Discussion by introducing illustrative design-oriented examples that demonstrate how the results derived from Figs. 4–7 can inform practical sensor design decisions. These examples highlight the role of crossover frequencies, dominant noise regimes, and near-plateau bandwidth in guiding trade-offs between mechanical, electronic, and digital subsystems.
These modifications improve the overall structure of the manuscript and strengthen the connection between the theoretical framework and its practical applications.

Figure 6 and 7. In both these figures, panel (a) is missing the x-label “Frequency [Hz]”.

In the current figure layout, panel (a) shares the horizontal axis with panel (b), where the label “Frequency [Hz]” is already provided. For this reason, the label was not repeated in panel (a) to avoid redundancy.

The abbreviation ENOB is used several times in the manuscript, but it is never defined.

The abbreviation ENOB (Effective Number of Bits) has now been defined at its first occurrence in the manuscript.